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Investigation of Dust Sources and Control Technology for Longwall Plow Operations

By John J. McClelland and Robert A. Jankowski

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cfm	cubic foot per minute	mg/m^3	milligram per cubic meter
ft	foot	min	minute
ft/min	foot per minute	pct	percent
gpm	gallon per minute	psi	pound per square inch
h	hour	s	second
in	inch		

INVESTIGATION OF DUST SOURCES AND CONTROL TECHNOLOGY FOR LONGWALL PLOW OPERATIONS

By John J. McClelland[1] and Robert A. Jankowski[2]

ABSTRACT

The Bureau of Mines conducted a study of longwall plow operations to identify dust sources and existing control technology. Three longwalls employing either the high-speed overtaking or conventional method of mining were surveyed. Principal operating parameters and on-site dust control technology at the time of each survey are described. Short-term gravimetric and instantaneous sampling results are discussed in detail. The relationship between longwall dust levels and dust control technology was examined.

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INTRODUCTION

The plow is a continuous mining machine equipped with a static set of cutting bits, positioned at a predetermined depth and height, for mining in both directions along a longwall face. The plow is pulled in either direction by a heavy-duty chain. The broken coal is loaded onto an armored flexible face conveyor which, with the aid of hydraulic rams, holds the plow to the coal face, thereby causing the bits to bite into the coal as they are pulled along it (fig. 1).

Coal plows were initially developed in the Federal Republic of Germany (FRG) in the 1940's for mining friable coal seams less than 4.3 ft thick (1).[3] At the present time, they are used on 50 pct of the longwalls in the FRG (2). The first application of coal plow on a longwall face in the United States was in 1951 at a southern West Virginia coal mine (3). The growth of plows in the U.S. coal market has been limited by advances in thin-seam shearer technology. Today, plow longwalls represent a small percentage of U.S. longwalls and are primarily located in the Appalachian coal fields.

Two mining methods are commonly employed in longwall plow operations: (1) the conventional method, which uses a plow speed of less than 125 ft/min, and (2) the high-speed overtaking method, which uses a plow speed of more than 300 ft/min. With the conventional method, the plow runs more slowly than the conveyor. This method is usually used in thick-coal seams, where the faster conveyor clears the larger product more

[3]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

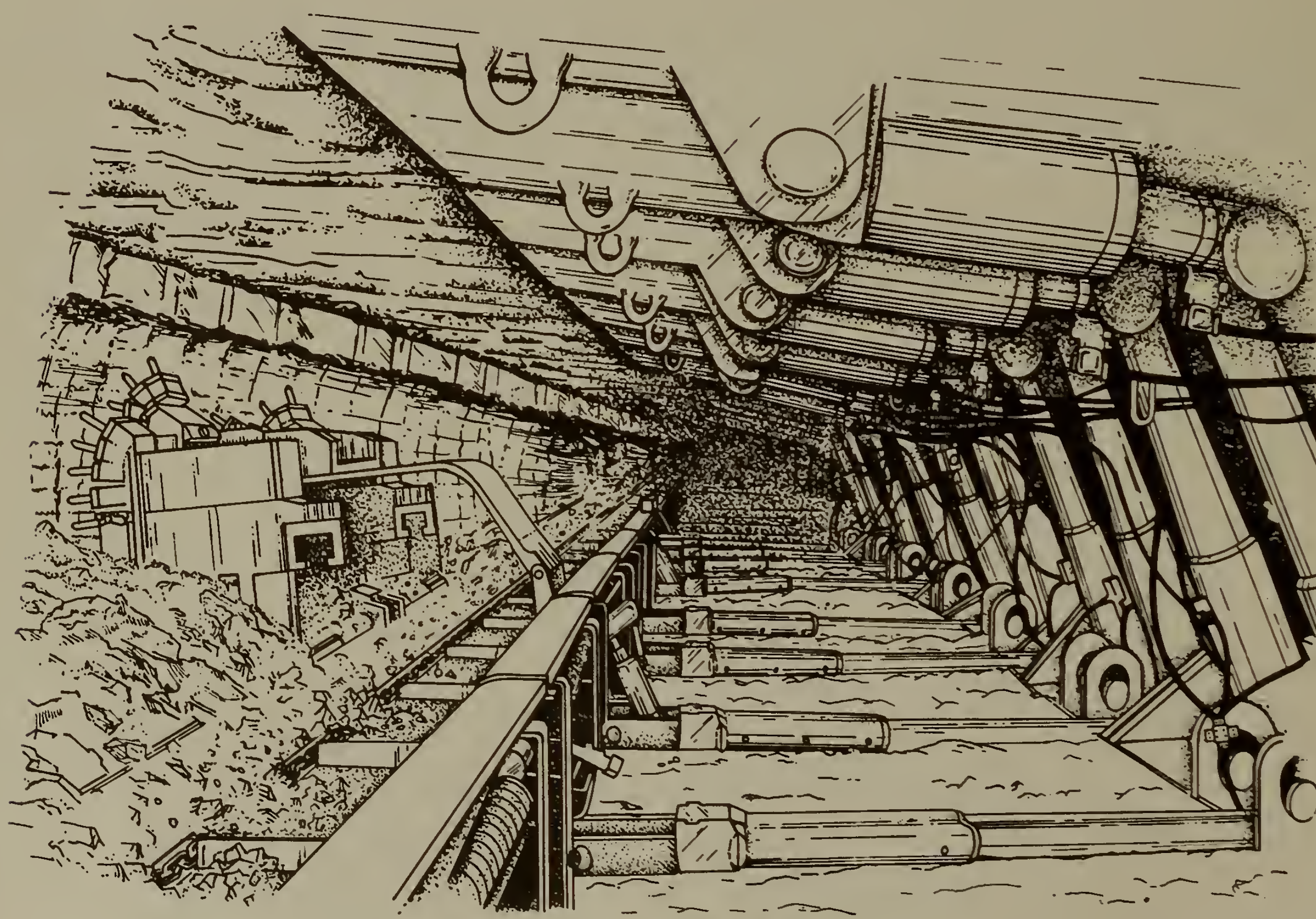

FIGURE 1.—Longwall plow face.

easily. With the high-speed overtaking method, the plow travels much faster than the conveyor. This method is generally used for seams less than 42-in thick because of the high output potential. Uniform loading of the face conveyor is achieved by maintaining an optimum speed differential of 2:1 to 3:1 between the plow and conveyor (4).

Plows are generally considered to produce less dust than shearers since the plow's method of attack produces a larger product (5). However, it is also considered more difficult to control these lower dust levels. A variety of control techniques are available to the operator. A sequentially activated spray system mounted on a face conveyor is the most popular and widely employed control technique. Its purpose is to suppress dust in the vicinity of the plow; it does this by operating several groups of water sprays ahead of and behind the plow. Another technique of interest is a hose-handling, plow-mounted water-spray system that has been tried repeatedly, but with only limited success (6). Severe operational problems are often encountered with the trailing water hose. These problems far outweigh the marginal improvements in dust reductions. Water infusion, whereby water is injected into the coal ahead of the face, can be a beneficial supplement to existing conventional dust control methods (7). However, costs and coal seam infusibility often dictate whether it is a viable option.

The Bureau of Mines began investigating plow operations when a longwall census indicated that average respirable dust levels for the designated occupations exceeded the 2.0-mg/m^3 dust standard. In addition, a background literature search revealed that virtually no work has been done on plow operations in recent years.

This report presents the results of three underground studies of both high-speed overtaking and conventional plow operations. The purpose of each survey was to identify and report on dust sources and existing longwall control technology.

TEST SETUP

IN SITU CONDITIONS

Three mines were surveyed to identify dust sources and control technology on conventional and high-speed overtaking plow operations. The principal operating parameters for the mines surveyed are shown in table 1.

TABLE 1. - Principal operating parameters

Operating parameters	Mine A	Mine B	Mine C
Plowing method............	Conventional......	High speed.......	High speed.
Plow speed........ft/min..	132..............	354..............	356.
Conveyor speed....ft/min..	274..............	181..............	193.
Depth of cut..........in..	4................	3-8..............	2-3.
Seam......................	Pocahontas No. 3..	Beckley..........	Lower Freeport.
Seam height...........in..	48...............	46...............	45.
Face length...........ft..	548..............	482..............	600.
Overburden............ft..	600-900..........	900-1,000........	450.
Moisture content.....pct..	1.47.............	5.76.............	1.4.
Water infused.............	No...............	No...............	No.
Hardgrove index...........	>100.............	85...............	84.
Average face air velocity.........ft/min..	570..............	560..............	370.
Roof composition..........	Shale............	Shale to slate...	Shale with occasional sandstone.
Floor composition.........	Shale............	Slate with coal laminations.	Clay.

The following briefly describes the on-site application of existing control technology:

Mine A: The primary means of controlling dust along the face was a manually operated, constant fullface water-spray system. Twenty-seven spray blocks were mounted along the face conveyor spillplate at 20-ft intervals. Each block consisted of one nozzle operating at 100 psi. A crusher, mounted on the face conveyor located upwind of support 15, was equipped with three nozzles on its intake side. Two sets of 10 flat-fan water-sprays were mounted at the face-conveyor-to-stageloader and stageloader-to-belt transfer points that controlled dust in the headgate area (one set of sprays at each transfer point). The transfer-point sprays were enclosed with brattice. Observations revealed that very few transfer-point water sprays worked. A Wendon[4] wetting agent was used extensively throughout the section.

Mine B: An electromechanically activated sequential water-spray system was the primary means for controlling dust along the face. Ninety-six spray blocks, mounted at 5-ft intervals along the face conveyor spillplate, were sequentially activated in groups of 12 by electric solenoids. As the plow moved along the face, one group of sprays closed while the preceding group opened, thus keeping the plow enveloped with water at all times. Each spray block contained one nozzle of the adjustable flat-fan type, operating at 30 psi. Because the water sprays were the adjustable type, orientation within a spray block was random. Cone sprays operating at 85 psi were used to control dust at transfer points. One set of two sprays was mounted at the face conveyor-to-stageloader transfer point, and one set of two sprays was mounted at the stageloader-to-belt transfer point. It was observed that stageloader-to-belt water sprays were clogged and no sprays were used at the crusher.

Mine C: A sequential water spray system, similar to mine B's system, was used to control dust along the face. Twelve groups of 10 spray blocks were sequentially activated by electric solenoids. Spray blocks were mounted at 5 ft intervals along the face conveyor spillplate. As part of a separate ongoing evaluation by the mine, three types of water sprays were used along the face: (1) atomizing, (2) 1/16-in jet, and (3) 3/32-in jet sprays. Each block contained 3 nozzles of the various types, with each nozzle operating at 160 psi. Spray blocks were oriented downwind, with spray coverage over the conveyor and lower third of the face. Eighteen water sprays, operating at 25 psi, were used to control dust in the headgate area. Sets of six water sprays were mounted, near the face-conveyor-to-stageloader transfer point, at the stageloader-to-belt transfer point, and on the intake side of the stageloader-mounted crusher. Brattice was used to cover portions of the stageloader and belting was used to enclose the crusher and crusher-mounted sprays. Because of poor headgate roof conditions, observations revealed that the crusher would frequently produce high concentrations of dust while handling the fallen roof rock.

SAMPLING STRATEGY

Instantaneous and short-term gravimetric sampling methods were used to isolate and quantify potential sources of respirable dust.

Four gravimetric sampling stations were identified along the headgate and face. Sets of two gravimetric samplers each were stationed in the last open crosscut, at two headgate locations (approximately at shields 3 and 15), and at the tailgate (about 15 shields from the tail entry). Face-side gravimetrics were suspended from roof support canopies over the walkway. Eight gravimetric samplers were used as part of each day's sampling. No

[4]Reference to specific equipment does not imply endorsement by the Bureau of Mines.

8-h, full-shift sampling similar to compliance sampling was performed.

A MIE RAM-1 instantaneous dust monitor was used to measure dust concentrations generated by the plow and roof support movements. RAM-1 data are normally recorded on handheld audio tape recorders. After the survey of mine A, tape recorders were replaced with Mine Safety and Health Administration (MSHA) approved solid-state digital data loggers. Each logger was preprogrammed to record one output voltage level from the RAM-1 every second, for a total run time of 34 min. The 1-s averaging and recording of output voltage insured accurate and consistent monitoring of dust levels at each sampling station. A portable microcomputer, in combination with communication software, was later used to retrieve and store logger data onto floppy disks for future analysis.

Stationary instantaneous sampling was conducted at locations upwind of support 35 during each survey. Earlier attempts to sample near the tailgate were unsuccessful because concurrent upwind activities produced unpredictable background dust levels. By selecting two sampling locations in close proximity and upwind of support 35, it was possible to overcome restricted visibility and conduct accurately timed surveys of upwind and downwind face activity. Time study results were used to interpret logger data by identifying events that may have had an adverse effect on dust levels. For example, it was important to make note of the start and stop times of the plow, face conveyor, and support movement activity; changes in cut direction; and the location of the plow with respect to each sampling location.

SURVEY RESULTS

Gravimetric results are shown in table 2 and figure 2. Table 2 presents the average concentration measured at each sampling station for all three mines surveyed. Based on this information, respirable dust sources have been identified and their contributions to face workers' exposure computed. Respirable dust sources fall into three groups: (1) sources that occur outby and represent section intake dust, (2) sources upwind of support 15 (specifically stageloader and crusher-generated dust), and (3) sources that occur along the face (namely coal transport-, plow-, and support-generated dust). Figure 2 illustrates the significance or insignificance

TABLE 2. - Gravimetric results: average dust concentrations[1] in milligrams per cubic meter

Sampling station	Mine A	Mine B[2]	Mine C
Section intake..	0.2	0.5	0.1
Support 3.......	1.1	2.5	1.3
Support 15......	2.1	2.4	1.3
Support (tail-15)......	3.1	NA	2.4

NA Not available.
[1]Concentrations are not calculated MRE equivalents.
[2]Data has been normalized for production.

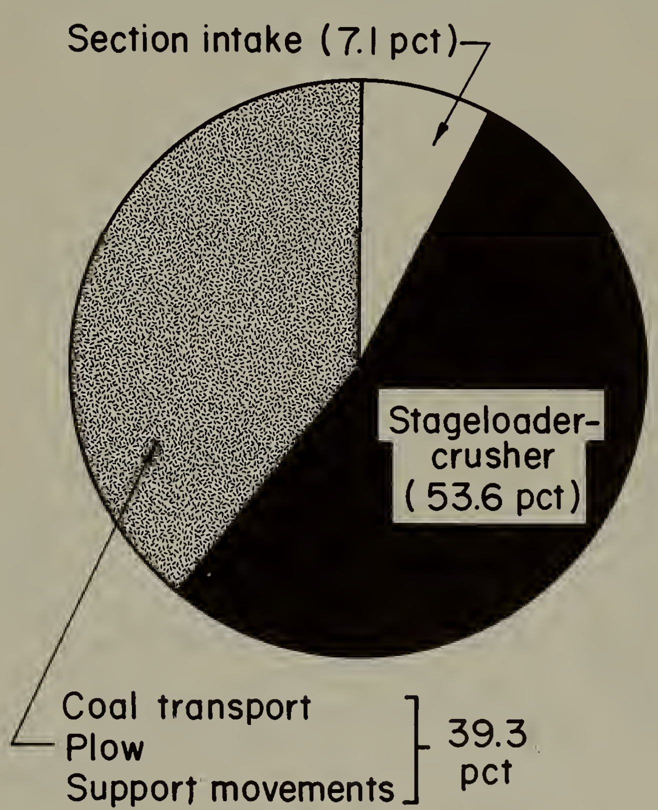

FIGURE 2.—Typical respirable dust sources.

of each group based on the survey average of source contributions.

Instantaneous sampling was conducted to identify the significance of group 3 dust sources. Individual segments of recorded instantaneous data were analyzed to identify source contributions from plow and roof support movements. Current sampling methodologies did not permit independent evaluation of coal transport dust. Figures 3 and 4 represent typical time history plots of instantaneous dust levels for mines B and C, respectively. Figure 3 shows the significance of support movements for face dust levels; figure 4 presents dust levels measured near the plow.

Mine A: Gravimetric results showed that the most significant change in dust levels occurred upwind of support 15. Sixty-eight percent, or 2.1 mg/m^3 of respirable dust along the face, was measured at this location. Approximately 0.9 mg/m^3 was generated by the stageloader upwind of support 3 and 1.0 mg/m^3

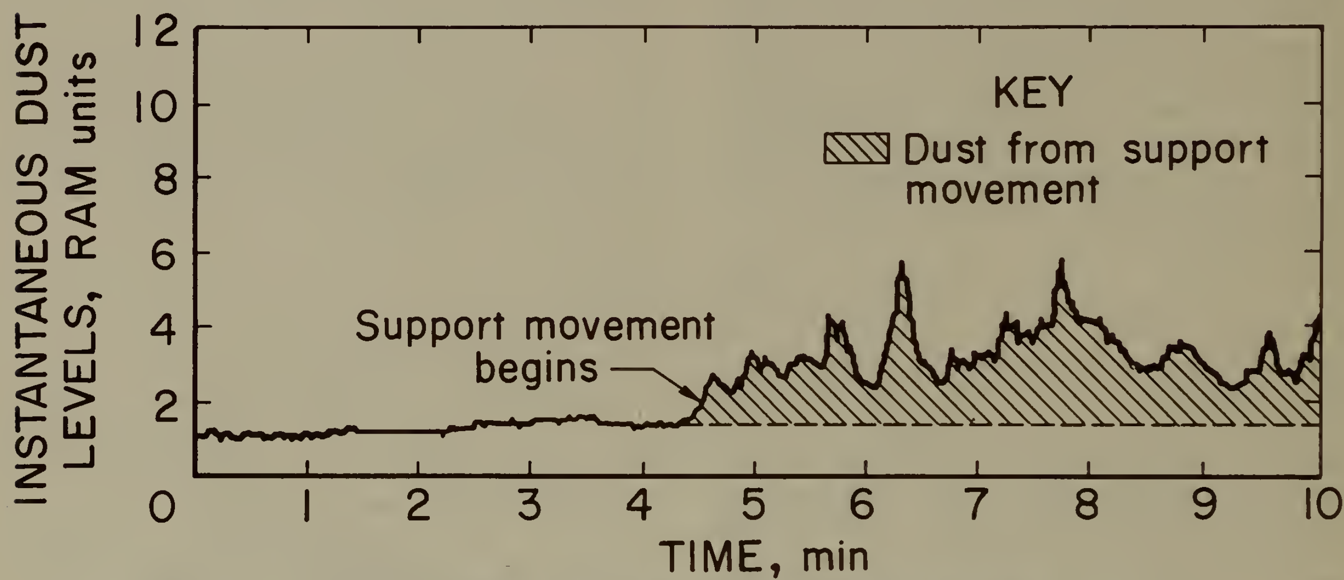

FIGURE 3.—Instantaneous roof support dust concentrations at mine B.

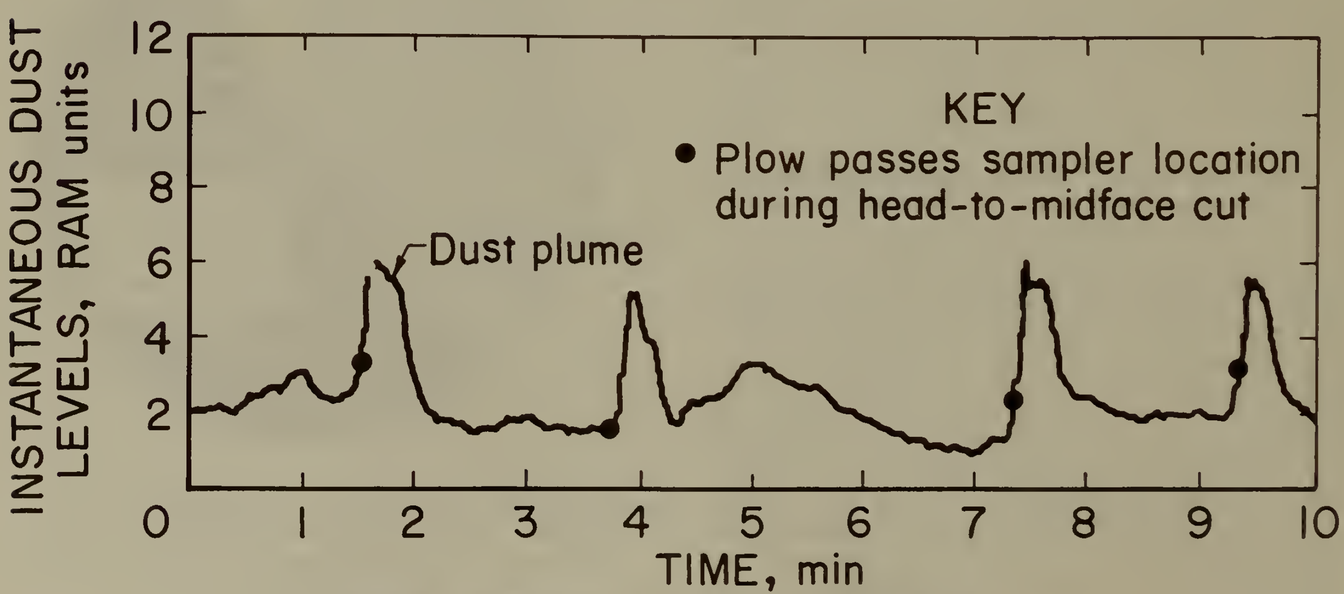

FIGURE 4.—Instantaneous dust concentrations by a plow at mine C.

by a crusher mounted on the face conveyor upwind of support 15. Coal transport, the plow, and roof support movements generated 1.0 mg/m^3 of dust along the face as measured at the tailgate support.

Plow-generated dust is identified as the computed difference between dust levels measured on the intake and return-air sides of the plow. Instantaneous results indicated that plowing generates, on average, less than 0.2 RAM[5] units of dust, regardless of cut direction.

Concentrations measured downwind of two support operators were averaged, and intake levels subtracted to identify dust contributions from support movements. Roof support movements generated 1.8 RAM units of dust, with peak concentrations as high as 37.2 RAM units.

Mine B: Once again, a significant amount of dust was generated at the headgate by the stageloader-crusher. Based on available gravimetric data, results showed that 2.0 mg/m^3 of respirable dust was generated inby the last open crosscut and upwind of support 3. This is a significant contribution by any measure. Because of equipment malfunctions, gravimetric data are not available for the tailgate sampling location.

Figure 3 shows a typical time history profile of instantaneous dust levels before and after the start of upwind support movements. Best estimates are that support movements generated an average of 1.4 RAM units of dust. Figure 3 also illustrates the insignificance of plow-generated dust. During the first 4-1/2 min of sampling, and before the start of upwind support movements, there was virtually no measurable change in dust levels, despite the fact that the plow made two complete passes of the face (a pass equals one cut from head to tail plus one cut from tail to head).

Mine C: Results from this survey were essentially the same as the first two surveys. Forty-six pct of the respirable dust along the face (1.2 mg/m^3) was generated upwind of support 3 by the stageloader-crusher. An additional 46 pct was generated along the face (as measured at the tailgate support) by coal transport, plowing, and roof support movements.

Figure 4 shows a typical profile of instantaneous dust levels measured while a plow was mining in the vicinity of the stationary sampling location. Unlike plows in the other mines surveyed, this plow was found to produce a measurable difference in respirable dust levels. During the head-to-midface cut, a plume of dust was observed traveling with and on the intake air side of the plow. At times, dust levels reached instantaneous peaks of 7.0 RAM units. Since dust is generated in only one cut direction and exposure to this dust is of short duration, it is safe to assume that the plow was an insignificant dust source. Support dust was generally found to be insignificant, except where clay veins were present.

DISCUSSION

Instantaneous and short-term gravimetric sampling methods were used to identify respirable dust sources along high-speed overtaking and conventional plow operations. Gravimetric results provided information on three dust source groups: section intake; stageloader-crusher; and coal transport, plow, and support movements. Instantaneous results helped to identify the significance of plow- and support-generated dust.

The impact of a dust source on face workers' exposure is directly related to its frequency of occurrence (or time fraction of the mining cycle) and to the workers' location along the plow face, with respect to the dust source. For

[5] A RAM unit is the relative numerical output from the RAM-1 and approximates respirable dust levels in milligrams per cubic meter.

example, a stageloader-crusher operates 100 pct of the actual mining time, and regardless of the operators' location along the face, they are exposed to this dust source 100 pct of the time. On the other hand, upwind support movements occur only 25 to 50 pct of the mining time. Although exposure to this dust source is less frequent, a tailgate worker on a plow face is exposed to many more upwind roof support movements than a worker located near the headgate. Theoretically, dust exposure levels for the tailgate worker should be higher. The logic is the same for exposure to plow-generated dust as it is for exposure to support dust; the longer a worker stays on the return air side of a plow, the greater the exposure.

On the longwall plow faces surveyed by the Bureau, the stageloader-crusher was found to be the most common and significant source of dust. Typically, 54 pct of the dust responsible for face worker exposure comes from the stageloader-crusher. Despite the mines' efforts to control this dust source, existing control systems were inadequate.

A number of low-cost alternatives are available for controlling stageloader-crusher dust. Strategically located water sprays mounted on an enclosed stageloader-crusher, or a water-powered scrubber that cleans the air inside it, can be very effective in reducing dust levels. An enclosed stageloader-crusher spray system consisting of twelve hollow-cone sprays (20 gpm total water flow) located in the crusher, at the intake and discharge side of the crusher, and immediately after the stageloader dump point, can reduce dust concentrations by 74 pct at the stageloader (fig. 5) (8). A water-powered scrubber mounted on a stageloader and supplied with approximately 9 gpm water at 500 psi, for an airflow of approximately 2,000 cfm, can reduce intake dust along the face by 50 pct (9). Although a water-powered scrubber offers excellent dust control, its application to plow operations may be limited by seam height.

Plow, coal transport, and support movements typically account for 38 pct of the dust responsible for face workers' exposure. Support-generated dust was a problem at mines A and B. Support dust problems normally occur when coal or some other highly friable roof material is ground and crushed during the advance and setting of roof supports (10). At mine A, the problem was a combination of

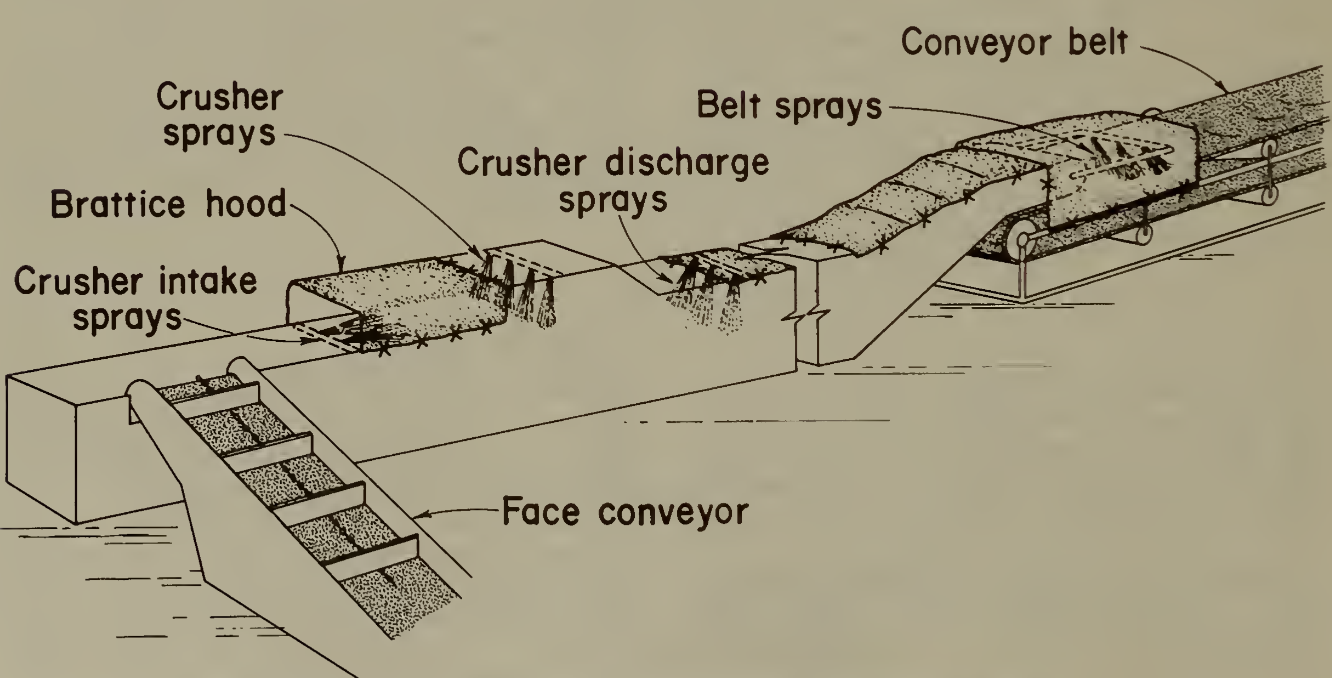

FIGURE 5.—Enclosed stageloader-crusher with strategic location of water sprays.

poor roof conditions and failure of the uncut coal to fall freely away from the roof. At mine B, the problem was primarily roof coal. The solution to this problem is not quite clear. For plow operations, it is common and often necessary to mine at a cutting height that is lower than the seam height, to prevent the plow from riding into the roof and interrupting production. However, if the remaining uncut coal fails to break and fall freely away from the roof prior to the movement of supports, it can create a dust problem. Alternatives may include adjusting the cutting height, at the risk of interrupting production, or to introduce modified support-setting techniques. Attempts have been made to attach water sprays to roof support canopies and to wet the zone ahead of the support along the roof. Maintenance often becomes a problem, and it is usually difficult to prevent the sprays from being torn off.

Finally, plow-generated dust does not present much of a problem. Only at mine C was a measurable change in dust levels observed. Since face personnel do not travel with the plow, unlike shearer operators who remain with the machine at all times, exposure to a short-duration dust cloud is insignificant. (For mine C, exposure normally did not last longer than 30 seconds for every other cut). This suggests that existing dust control technology is doing an excellent job of controlling plow-generated dust, or that the plow produces very little dust in the respirable size range.

CONCLUSIONS

The stageloader-crusher is a primary source of dust on longwall plow operations. Stageloader-crushers can generate over 60 pct of the dust along the face. The mines surveyed had all made attempts to control this dust source, but had met with little success. Implementation of stageloader-crusher control techniques means strategically locating water sprays under the brattice of an enclosed stageloader, or mounting a water-powered scrubber to clean the air inside the machine. Either technique is relatively inexpensive and with proper maintenance can produce significant dust reductions.

Support-generated dust presents a dust control problem when uncut coal fails to fall freely from the roof before advancement of the supports. The residual roof coal is crushed by roof support movements, possibly producing high concentrations of dust. This can be a serious problem for many workers who must remain at stationary locations along the plow face. Since dust exposure is a function of worker location along the face relative to the dust source, a tailgate support operator is exposed to many more upwind roof support movements than is a headgate operator, and theoretically should be exposed to higher dust levels. Two of the three mines surveyed had support dust problems. The solution to controlling this dust source remains unclear. It may prove more cost-effective to pursue control techniques for other more significant sources of dust, specifically the stageloader-crusher.

Surprisingly, plow-generated dust was found to be insignificant. This suggests that existing control technology, in the form of constant or sequentially activated face-conveyor-mounted water sprays, is adequate. Each system has its advantages. A sequential system optimizes the use of water by minimizing water flow and maximizing water pressure in the vicinity of the plow. It also reduces the amount of nuisance water, in the form of mist and runoff. On the other hand, a constant full-face system would ensure better saturation of the coal by wetting the coal well in advance of the cut and maintaining this saturated state during coal transport.

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